Surviving Mars: In-Situ Production of Oxygen and Water

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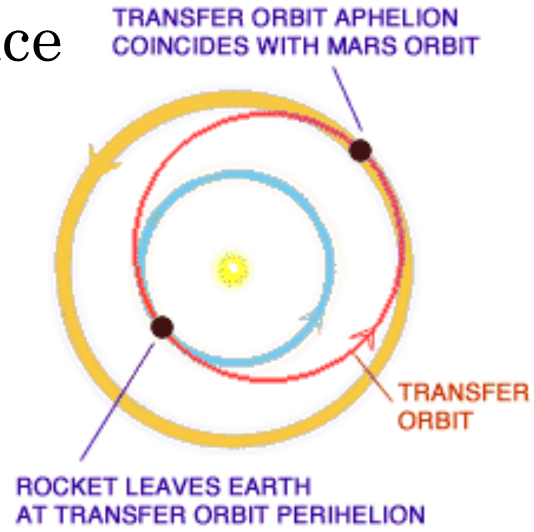
Motivation for a Manned Mission

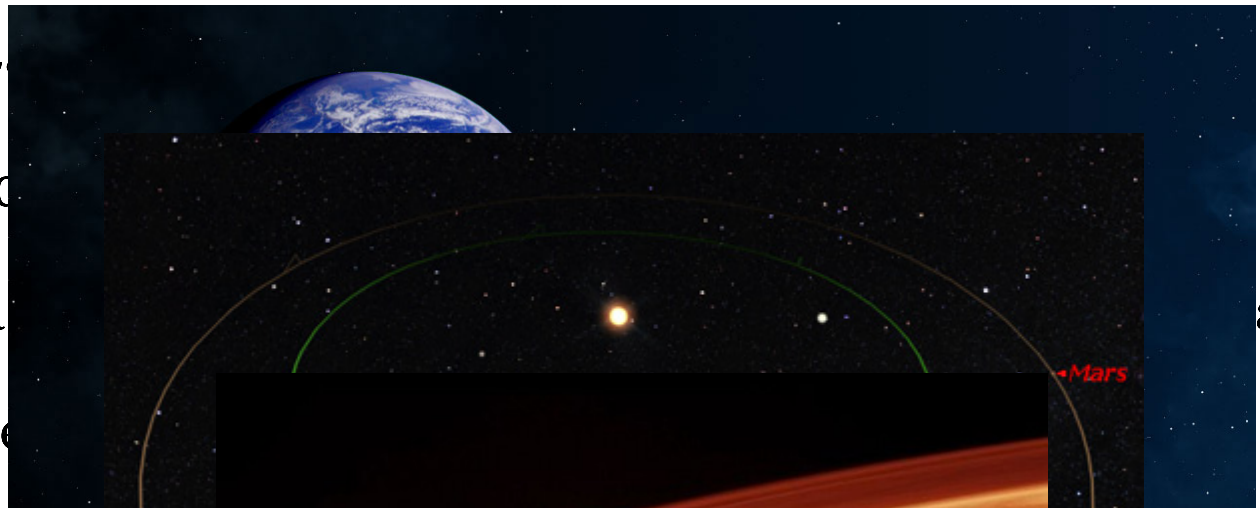
- Various advantages in motion and reasoning
- Scientific advances in astro-chemistry/biology
- Next logical step in exploration, most Earth-like

- Cost in range of $10-100 billion
  - Est. depends on payload and working model results
- 6 months travel, 525 sols on surface
- Hohmann transfer orbit
  - Heliocentric ellipse
  - Uses least amount of fuel



Overview of Mars

- 50% diameter and 40% gravity of Earth
- Orbit
- Synoc
- Avera a)
- Tempe



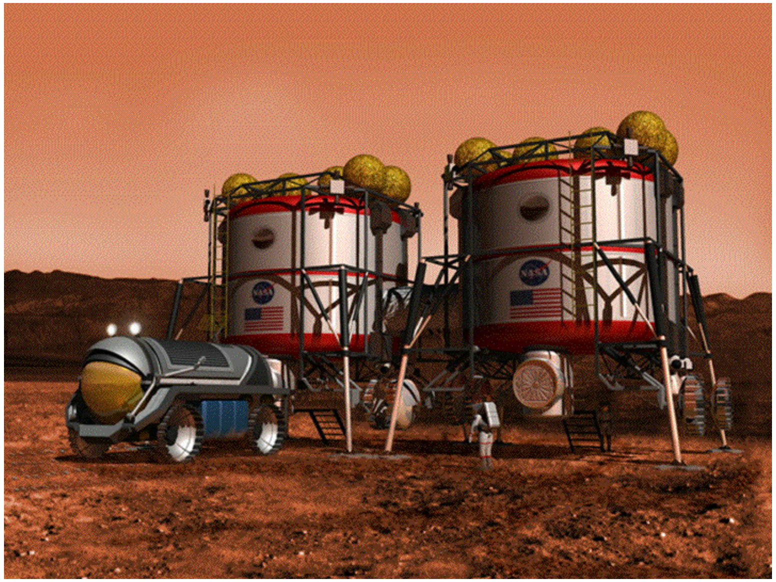
Carbon dioxide	96.0%
Arg	1%
Nitro	9%
Oxy	45%
Carbon m	557%

Problems

"I've a feeling we're not in Kansas anymore…"

- Not enough oxygen
- No readily available water
- Low atm. pressure
- Low temperatures
- Too much carbon dioxide

Survival for 525.5 sols

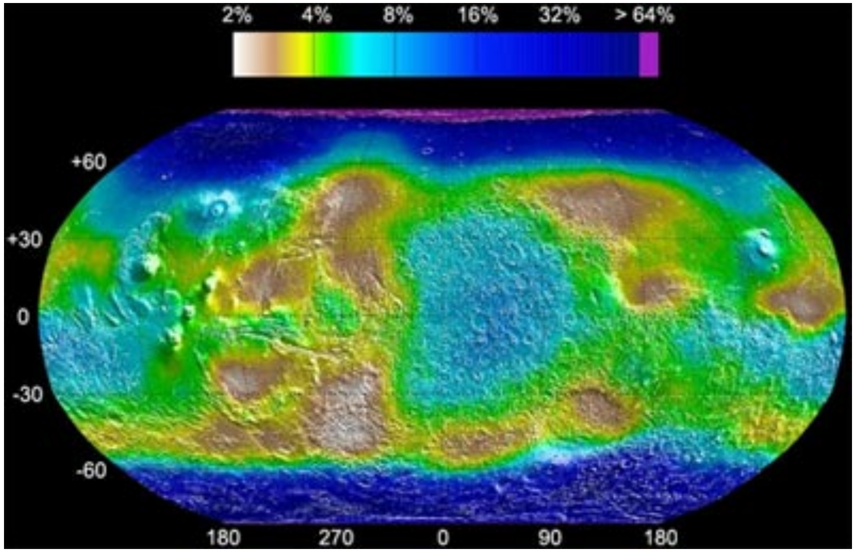


Artist's depiction of a pressurized habitat utilizing Mylar and radiators to help control temperature

Solution For Oxygen and Water

- In-situ resource utilization (extra $3 billion otherwise)
  - Process system utilizing atmosphere and soil
- Send system one synodic period before (ex. 2028/2031)
  - Run for 720 sols before astronauts, 1246 sols total
- Land at ~10-15° north of equator
  - Shock-absorbing material and powerful thrusters

Season in Northern Hemisphere	Number of Sols (days)
Spring	194 (199.3)
Summer	178 (182.9)
Autumn	142 (145.9)
Winter	154 (158.2)
Total	668 (686.3)



In-Situ Processes

	Oxygen	**Water**
Total (kg)	1815	5184
Per sol needs for Four (kg)	3.45	9.86
Per sol production (kg)	1.46	4.16

- Water Electrolysis
  - **$H_2O \rightarrow H_2 + ½\, O_2$**
- Solid Oxide Electrolysis
  - **$CO_2 \rightarrow CO + ½\, O_2$**
- Sabatier Process
  - **$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$,** $\Delta H = -165$ kJ/mol
  - Uses atmosphere, produces methane and water
- Reverse Water Gas Shift (RWGS)
  - **$CO_2 + H_2 \rightarrow CO + H_2O$,** $\Delta H = 41$ kJ/mol
  - Uses atmosphere, produces carbon monoxide and water

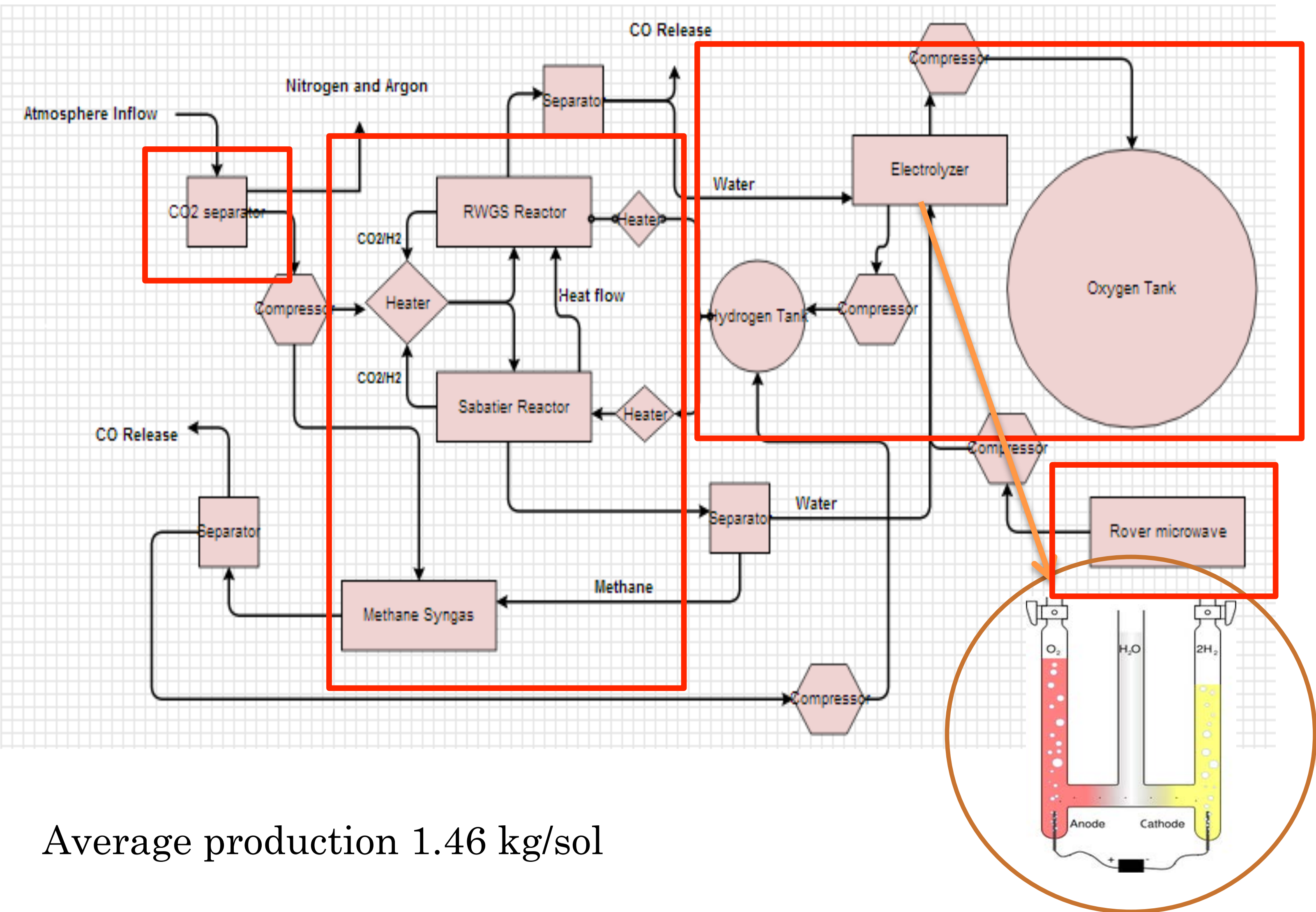
Decision Matrix for Creating Oxygen

		Solid Oxide		Sabatier		Sabatier/RWGS/Syngas 95%/80%/75%		RWGS	
Criteria	Weight	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Efficiency	35	9	315	8	280	9	315	5	175
Cost	25	5	125	7	175	6	150	4	100
Power	20	3	60	7	140	7	140	4	80
Supplies	10	9	90	4	40	6	60	9	90
Practicality	10	2	20	8	80	9	90	5	50
Total	100	27	610	34	715	**37**	**755**	27	495

$2.95\ CO_2 + 0.3\ H_2O + 0.175\ CH_4 \rightarrow 2.025\ CO_2 + 1.5\ O_2$

Syngas: $CO + 2\ H_2 \rightarrow$

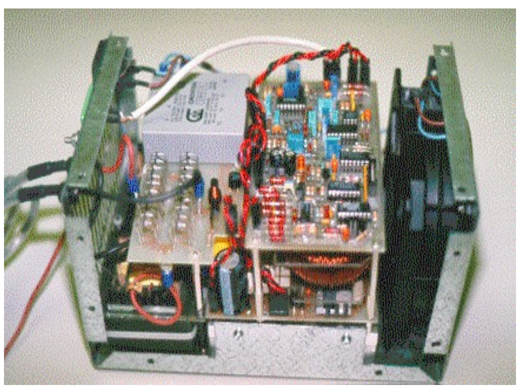
MAKING THE OXYGEN



Average production 1.46 kg/sol

Making the Water: Rover Microwave

- Soil density 1.52 g/cm^3 (5% by mass is 7.6 kg/m^2)
- Use microwave to extract
  - Must produce >2.5 kW, use two magnetrons
- Wheel base to move
  - Must cover circle of radius 15 m
- Cryocooler pan and tubes



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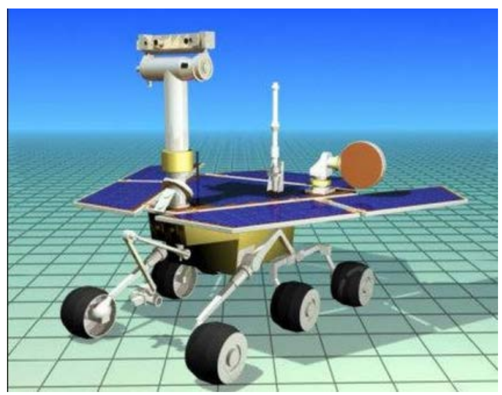

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Average production 4.16 kg/sol

Power Operation

- Microwave and rover: 2700 W solar power TFSC
  - 90 W/m^2 average, accounting for dust and cleaning
- Process syste… ion power
  - 2000 W_h an…

Scaling Relations fo…
(mass in kg, no red…

							500 kg/day	
S/E-RWGS								
sorption pump…							320	24,000
chemical syn…							404	150,000
controls	2	20	4	40	8	80	12	160
lines, valves, misc	3	0	9	0	27	0	84	0
refrigerator	2.5	105	10	1050	40	10,500	160	105,000
Total	*16.5*	*299*	*51*	*2830*	*199*	*27,980*	*980*	*279,160*

- 11.5 hrs/sol in spring/summer, 10.5 hrs/sol in autumn/winter

System Flow Rates

Before astronauts arrive (424 Sp/Su 296 Au/Wn, 7984 hrs)

Sabatier (g/h)			RWGS (g/h)			Syngas (g/h)		
H_2	CH_4	H_2O	H_2	CO	H_2O	CH_4	CO	H_2
21.90	41.62	93.64	5.476	61.33	39.43	41.62	109.25	7.936

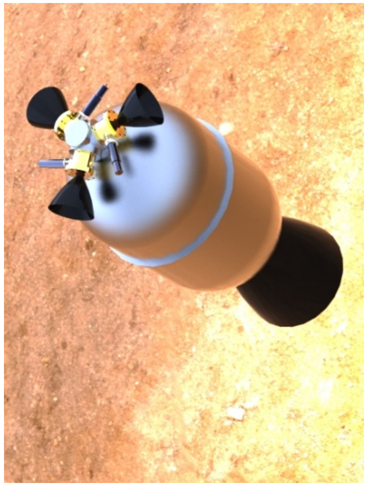
- 373 g/h air
- 390 g/h water
- Limiting factor in tank volumes

After astronauts arrive (247.5 Sp/Su 278 Au/Wn, 5765 hrs)

Sabatier (g/h)			RWGS (g/h)			Syngas (g/h)		
H_2	CH_4	H_2O	H_2	CO	H_2O	CH_4	CO	H_2
22.14	42.06	94.63	5.534	61.98	39.85	42.06	110.4	7.886

- 374 g/h air
- 377 g/h water
- 140 g/h oxygen to habitat

Future Prospects



- Troubleshooting
  - Dust and thermal coverings
  - Rigorous testing of parts
- Tackle other problems
  - Supply return fuel
  - Lack of magnetosphere
- Renewed interest in space and technology
  - Advances for use on ISS and industry
  - More funding for NASA
  - Exponential advances in further exploration